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FORMATION OF DIMETHYL ACETALS OF D-GLUCOSE, D-XYLOSE, AND L-IDOSE IN THE PRESENCE OF STRONTIUM IONS*†

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ABSTRACT

The dimethyl acetals of D-glucose, D-xylose, and L-idose were prepared in 15–25% yield by Fischer glycosidation in the presence of strontium or calcium chloride, whereas no dimethyl acetal was isolated in the absence of these cations. Complexing of these dimethyl acetals with cations was indicated by n.m.r. spectra and by electrophoresis. From the reaction of L-idose, the two (previously unknown) methyl L-idofuranosides were isolated.

INTRODUCTION

Previous papers from this laboratory demonstrated the use of n.m.r. spectroscopy in determining the extent of complexing of a number of aldoses with cations[2], the configurational requirements for complexing to occur[2–4], and the application of complexing with calcium and strontium chloride in the preparation of methyl glycosides by Fischer glycosidation[1,5]. The proportion of the glycosides which form complexes with cations is considerably increased under these conditions. This paper reports our findings of the effect of alkaline-earth cations in the Fischer glycosidation of D-glucose, D-xylose, D-galactose, and L-idose, sugars which do not possess the required configuration for complex formation in their ring forms, namely, an axial–equatorial–axial arrangement of three hydroxyl groups on successive carbon atoms of the tetrahydropyran ring, or a *cis–cis* relationship on successive carbon atoms of the tetrahydrofuran ring[2,6].

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[*] Dedicated to the memory of Dr. Hewitt G. Fletcher, Jr.

[†] Complexes of Carbohydrates with Metal Cations: Part VI[1].

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Initially, experiments were performed with D-glucose and D-galactose, in the expectation that the presence of a complex-forming salt would have little effect on the composition of the mixture of isomeric glycosides when no component was capable of significant complex formation.

RESULTS AND DISCUSSION

The first experiments on the reaction between D-glucose and methanol containing either 5 or 50mM hydrochloric acid showed that the addition of strontium chloride to the reaction mixture did alter the proportions of products obtained after 23 h (Table I). In particular, a fifth product of reaction, in addition to the two glucofuranosides and two glucopyranosides, was detected when strontium chloride or calcium chloride was present during the glycosidation, but not when they were absent. Analysis by g.l.c. of the acetylated products of the reaction, using the silicone copolymer ECNSS-M, suggested that the additional component could be methyl α-D-glucoseptanoside[7], but this was disproved by use of the stationary phase QF-1.

The mixture of products from the 24-h reaction with 5mM acid in the presence of strontium chloride was fractionated, after removal of the salt, by elution with water from Bio-Rad AG1 (OH^-) resin. Polarimetric monitoring showed a good separation of the five components. The first, second, fourth, and fifth fractions contained the methyl α- and β-D-glucopyranosides and methyl α- and β-D-glucofuranosides, respectively. The order of elution of the glycosides agrees with that reported by Baddiley and co-workers[8]. The third fraction contained the component that was not detected when strontium chloride was omitted. It crystallised readily and had physical constants that agreed with those reported for D-glucose dimethyl acetal[9]. The identification was confirmed when the product was acetylated and compared with an authentic sample of penta-*O*-acetyl-D-glucose dimethyl acetal[9].

The surprisingly high yield of D-glucose dimethyl acetal led us to examine the reaction further, with a view to improving the yield and isolation procedure (see Table II). With 5mM hydrochloric acid in the reaction mixture, the amount of D-glucose dimethyl acetal reached a maximum at 4 h and thereafter remained constant. We later found that on heating methanol with strontium chloride and acetyl chloride, without D-glucose, there was a loss of acid, possibly as methyl chloride, which was complete after 8 h. When 50mM hydrochloric acid was used, the yield was highest (21%) at 30 min, and then decreased slowly during the next 30 h. Neither the use of an equal weight of calcium chloride in place of strontium chloride, nor increasing the amount of these salts in the reaction mixture, led to any improvement in yield; the effect of smaller concentrations of these salts or of other salts of calcium or strontium was not studied. No difference was found when β-D-glucose was used in place of α-D-glucose. It might be expected that complexing of a D-glucose dialkyl acetal with metal ions, which presumably leads to its stabilisation in the glycosidation mixture, would be greater in ethanol than in methanol. However, the yield of D-glucose diethyl acetal[10] was zero for strontium chloride and only 2% for calcium chloride, presumably because of the low solubility of these salts in ethanol.

TABLE I

COMPOSITION OF REACTION MIXTURE OF D-GLUCOSE AND METHANOL AFTER 23 h, AND RETENTION TIMES OF ACETATES

Compound	*Composition* (%)					*Retention time* (*min*)	
	5mM *HCl*		50mM *HCl*			*3% of ECNSS-M*	*1.5% of QF-1*
	(a) *No* $SrCl_2$	(c) 0.56M $SrCl_2$	(b) *No* $SrCl_2$	(d) 0.56M $SrCl_2$	(e) 0.80M $CaCl_2$		
α-Furanoside	25.3	29.7	3.3	13.7	13.6	6.1	3.1
β-Furanoside	47.5	40.3	5.4	21.1	21.4	7.2	3.5
α-Pyranoside	13.5	5.8	57.2	29.7	29.5	8.8	4.5
β-Pyranoside	13.7	3.7	34.1	27.7	27.9	10.4	4.5
Dimethyl acetal	0	20.5	0	7.8	7.6	11.7	5.8
α-Septanoside[7]	0	0	0	0	0	11.7	4.9
β-Septanoside[7]	0	0	0	0	0	10.2	4.6
D-Glucose	0	0	0	0	0	19.8	7.0

TABLE II

COMPOSITION OF REACTION MIXTURE OF D-GLUCOSE, METHANOL, 50mM HCl, AND 0.56M $SrCl_2$

Compound	*Composition* (%)			
	Time			
	10 min	*20 min*	*30 min*	*240 min*
α-Furanoside	17.8	23.0	21.4	19.4
β-Furanoside	32.4	38.0	41.2	34.6
α-Pyranoside	1.9	2.5	2.5	14.6
β-Pyranoside	1.8	2.3	2.4	13.7
Dimethyl acetal	14.0	18.2	20.9	17.7
D-Glucose	32.1	16.0	1.6	0.0

Results similar to those for D-glucose were obtained with D-xylose, and with 50mM hydrochloric acid in the presence of calcium or strontium chloride, the yield of D-xylose dimethyl acetal[11] was 25%.

When the same procedures were applied to D-galactose, D-galactose dimethyl acetal[12] was formed in a reaction mixture containing strontium chloride, but not in its absence (Table III). The yield of dimethyl acetal was, however, only 5.3%. On passage of the mixture of products through Bio-Rad AG1 (OH^-) resin, only the two methyl galactofuranosides were separated, the other three components emerging as a mixture. This could be resolved on a column of Bio-Rad AG50 (Sr^{2+}) resin, from which the order of elution was methyl α-D-galactopyranoside, methyl β-D-galactopyranoside, and D-galactose dimethyl acetal. Each compound was obtained crystalline and had physical constants in agreement with those given in the literature[8,12].

TABLE III

COMPOSITION OF REACTION MIXTURE OF D-GALACTOSE, METHANOL, AND 5mM HCl AT 22 h

Compound	*Composition* (%)	
	No $SrCl_2$	*0.56M* $SrCl_2$
α-Furanoside	17.0	22.4
β-Furanoside	57.3	61.1
α-Pyranoside	18.4	8.0
β-Pyranoside	7.3	3.2
Dimethyl acetal	0	5.3

We also studied the fractionation of the D-glucose reaction mixture on Bio-Rad AG50 (Ca^{++} or Sr^{++}) resin, after removal of calcium or strontium chloride, but the separation of the glycosides was less efficient that that with Bio-Rad AG1. However, this resin has the advantage that the dimethyl acetal is contained in the last fractions, well-separated from the glycosides. Attempts to remove calcium or strontium chloride and to effect fractionation of the reaction mixture in one operation by using Amberlite MB-3 mixed-bed resin led to complete loss of dimethyl acetal and no separation of the remaining glycosides.

Methanolysis in the presence of strontium chloride was also carried out with L-idose, and L-idose dimethyl acetal was obtained crystalline in 15% yield. Its acetate also crystallized and gave an n.m.r. spectrum which showed two methyl and five acetyl groups. Amongst the other products of the reaction were found the two (previously unknown) methyl furanosides; from an earlier methanolysis of L-idose, only the methyl pyranosides were isolated[13]. The structures and configurations of methyl α-L-idofuranoside and β-L-idofuranoside were assigned on the basis of optical rotation and n.m.r. spectra. The anomeric proton appeared at δ 4.88 and 5.01 with $J_{1,2} < 1$ and 3.7 Hz, respectively (*cf.* the spectra of the idofuranoses[14]). The acetylated furanosides showed n.m.r. spectra which could be fully analysed, and are compatible with the assigned structures[15].

The presence of strontium chloride in the methanolysis mixture therefore greatly increases the proportion of the dimethyl acetals. Ferrier and Hatton[16] found that the amount of D-xylose dimethyl acetal reaches a maximum of 2.5% in the methanolysis of D-xylose; in our experiments, over 25% was obtained. This increase must be due to complex formation with strontium ions. The ring forms of the sugars here discussed lack the steric arrangement required for complex formation[2,6], but the acyclic forms can adopt a conformation in which three successive hydroxyl groups are in an arrangement similar to the axial–equatorial–axial sequence. A study of the complex formation with alditols[17] has shown that a *threo–threo* arrangement of hydroxyl groups on three consecutive carbon atoms is particularly suitable for complex formation: the complex then has a planar zig-zag arrangement of the carbon chain. Glucitol and iditol readily form such complexes, and ready complex-formation would therefore be expected from the acyclic forms of glucose, idose, and xylose. The *threo–erythro* sequence of galactitol is less favourable for complex formation[17]; hence the yield of the galactose dimethyl acetal in our method is less. Glucose, idose, and xylose are the only aldo-hexoses and -pentoses which are expected to give a good yield of dimethyl acetals in the presence of strontium chloride.

Elution of the dimethyl acetals after the glycosides when reaction products from glucose and idose were passed through columns of Bio-Rad AG50 (Ca^{2+}) resin is evidence for preferential complexing between the dimethyl acetals and calcium ions, and further evidence for formation of complexes (in water) was obtained by paper electrophoresis. Relative cationic mobilities in calcium acetate solution of the four aldose dimethyl acetals and the four related alditols are shown in Table IV; the mobility is probably an approximate measure of the degree of complex-formation for each compound[17]. It is interesting that the dimethyl acetal migrates more slowly than the alditol in each case, although two rotamers of the acetal end-group contain the preferred complexing arrangement of oxygen atoms in contrast to only one rotamer of the alditol, and this might be expected to compensate for the large size of the acetal molecule. The difference may be due largely to the poorer complexing ability of a methoxyl, compared with a hydroxyl, group.

TABLE IV

ELECTROPHORETIC MOBILITIES OF THE DIMETHYL ACETALS AND RELATED COMPOUNDS

Compound	M_I[a]	M_N[b]	*Compound*	M_I	M_N
D-Xylose dimethyl acetal	0.16	0.60	Xylitol	0.19	0.67
D-Glucose dimethyl acetal	0.19	0.63	D-Glucitol	0.21	0.71
D-Galactose dimethyl acetal	0.12	0.77	Galactitol	0.17	0.85
L-Idose dimethyl acetal	0.19	0.65	D-Iditol	0.24	0.71
Methyl α-D-idopyranoside	0.01	0.42	Methyl α-L-idofuranoside	0.02	0.48
Methyl β-L-idopyranoside	0.025	0.45	Methyl β-L-idofuranoside	0.02	0.52

[a] Cationic migration relative to *cis*-inositol in 0.2M calcium acetate containing 0.2M acetic acid. [b] Anionic migration relative to nitrobenzene-4-sulphonate ion in 50mM disodium tetraborate.

Formation of complexes with cations is also seen in the upfield shifts of proton signals in the n.m.r. spectra of L-idose and D-glucose dimethyl acetals on addition of europium nitrate. The shifts are similar to those observed in the spectra of alditols[17]; the signal for H-3 shifts most in the spectrum of the glucose derivative, indicating that complexing occurs at O-2, O-3, and O-4.

The methyl aldofuranosides and the dimethyl acetal of an aldose are rapidly interconverted[16] in a solution in methanolic hydrogen chloride; complex formation therefore shifts the pseudo-equilibrium in favour of the dimethyl acetal. The α:β ratio of methyl D-glucofuranosides is approximately the same at the end of 23 h in the presence or absence of a complexing salt (Table I, 50mM hydrochloric acid). The conversion of furanosides into pyranosides is, however, much slower in the presence of the salts. Once the sugar has been converted mainly into the (more stable) methyl pyranosides, the proportion of the dimethyl acetal becomes small. G.l.c. analysis showed that, under the same conditions which provide good yields of D-glucose dimethyl acetal from D-glucose, methyl α- and β-D-glucofuranoside are converted into D-glucose dimethyl acetal together with much smaller amounts of D-glucose. Thus, the furanoside mixture could be recycled to provide more D-glucose dimethyl acetal.

We believe that the preparation of small quantities of all four of the above aldose dimethyl acetals by the procedures described could be carried out more easily than by methods utilizing aldose dithioacetals[9]. It is not known how satisfactory the dithioacetal route will be for the preparation of L-idose dimethyl acetal. The glycosidation reaction in the presence of a complex-forming salt could probably be used for preparation of larger quantities of the dimethyl acetals of D-glucose and D-xylose, although the latter is also readily available through the di-*O*-benzylidene derivative[19].

EXPERIMENTAL

General methods. — Calcium chloride was dried for 16 h at 220° and strontium chloride for 16 h at 120°. Methanol was dried by heating it with magnesium turnings.

Gas–liquid chromatography (g.l.c.) was performed with a custom-built instrument, using nitrogen as carrier gas, a hydrogen flame-ionization detector, and glass columns (3 × 1220 mm). Acetate derivatives of glycosidation mixtures and their separated components were prepared for g.l.c. by using acetic anhydride with sodium acetate catalyst. Separations of acetates derived from the glycosidation of D-glucose or D-galactose were performed on 3% of ECNSS-M on Chromosorb W at 193°. Derivatives from D-xylose reaction products were resolved on 1.5% of SE-30 on Chromosorb W at 200°. The composition of mixtures examined by g.l.c. was determined by weighing of peaks, and correlating the data with peak weights for standard mixtures.

In preparative experiments, glycosidation mixtures were separated on columns (40 × 2 cm) of Bio-Rad AG1-X2 resin (OH^- form, 200–400 mesh) or of Bio-Rad AG50W X2 resin (Sr^{2+} or Ca^{2+} form, 200–400 mesh) with water as eluent (flow-rate 1 ml/min), collecting fractions of constant volume (2, 5, 10, or 25 ml). Columns of Bio-Rad AG50W X2 were converted into the calcium form by treatment with aqueous calcium chloride, then aqueous calcium hydroxide until the effluent stream was alkaline, and then recently boiled water. This ensures that no residual hydrogen ions are left in the resin to hydrolyse the acetals. Fractions were monitored polarimetrically in a 0.1-dm cell of a Bendix automatic polarimeter with digital read-out, and fractions were combined on the basis of optical rotation and concentrated to dryness under diminished pressure at 40°.

Optical activities of the products were determined with the above Bendix system, and infrared spectra were obtained using KBr pellets in a Perkin–Elmer 137 instrument. The p.m.r. spectra were recorded on a Varian A-60 spectrometer with tetramethylsilane (δ 0.0) or acetone (δ 2.21) as internal standard. Paper electrophoresis was carried out with the equipment and procedures previously described[17,18] The relevant data are recorded in Table IV.

Reaction of α-D-glucose with hydrogen chloride in methanol. — (*a*) Anhydrous α-D-glucose (1.0 g) was added to methanol (20 ml) in which acetyl chloride (7.2 μl) had been dissolved (equivalent to 5mM HCl), and the mixture was heated under reflux for 23 h. The reaction mixture was treated with 3M sodium methoxide in methanol (35 μl), concentrated to 1 ml, and chromatographed on Bio-Rad AG1 resin.

(*b*) The previous experiment was repeated using 10 times the amounts of acetyl chloride (72 μl) (equivalent to 50mM HCl) and 3M sodium methoxide in methanol (0.35 ml).

(*c*) The experiment described in (*a*) was repeated with the incorporation of anhydrous strontium chloride (1.76 g). After being treated with sodium methoxide in methanol (35 μl), the mixture was evaporated, and the residue was stirred with 1.2M sodium hydrogen carbonate (19 ml). The precipitate of strontium carbonate was removed by filtration and the filtrate was concentrated to dryness. The residue was treated with anhydrous ethanol (20 ml), and the mixture was filtered. The filtrate, after concentration to 1 ml, was chromatographed on Bio-Rad AG1 resin.

(*d*) The experiment described in (*b*) was repeated in the presence of strontium chloride (1.76 g) and, after addition of sodium methoxide (0.35 ml), was worked-up as described in (*c*).

(*e*) The experiment described in (*d*) was repeated, except that strontium chloride was replaced by anhydrous calcium chloride (1.76 g). The results for (*a*)–(*e*) are shown in Table I.

(*f*) The experiment described in (*d*) was repeated except that the reaction was terminated after 10, 20, 30, or 240 min. The results are shown in Table II.

Preparation of D-*glucose dimethyl acetal.* — To a solution of anhydrous glucose (1 g) and anhydrous strontium chloride (1.7 g) in anhydrous methanol (20 ml) was added acetyl chloride (72 μl), and the mixture was boiled for 40 min. To the cooled mixture, a solution of sodium carbonate (1.6 g) in water (20 ml) was added, the mixture was filtered, and the residue washed with water. The combined filtrates were evaporated under diminished pressure, and the residue was extracted with boiling ethanol (2 × 20 ml) which was then filtered and evaporated.

The resulting syrup was applied as an aqueous solution to a column (3.8 × 55 cm) of Dowex 50W-X2 resin in the Ca^{2+} form and eluted with water; fractions (10 ml) were collected. The glucosides were eluted in Fractions 20–40. Fractions 49–65 contained the acetal; they were combined and evaporated under diminished pressure. The resulting syrup crystallised on standing in a desiccator to yield D-glucose dimethyl acetal (200 mg, 17%), m.p. 90–92°; lit.[9] m.p. 94–95°.

Reaction of α-D-*galactose with 5*mM *HCl in methanol.* — α-D-Galactose (1.0 g) was treated with methanol (20 ml) and acetyl chloride (7.2 μl) for 23 h in the absence or presence of anhydrous strontium chloride (1.76 g), and the reaction mixtures were processed as described for the corresponding reactions for D-glucose. The results are shown in Table III.

Reaction of D-*xylose with hydrogen chloride in methanol.* — D-Xylose (0.432 g) was added to methanol (10 ml) in which anhydrous strontium chloride (0.8 g) and acetyl chloride (36 μl) had been dissolved, and the mixture was boiled under reflux. At intervals (30, 40, 50, 60, 75, 180, 300, 450 min), samples (1.0 ml) were removed, added to M sodium hydroxide (0.1 ml), concentrated, and then diluted with water to 1.00 ml. A portion (0.25 ml) of each sample was eluted with freshly boiled water from a column (1.6 × 24 cm) of Bio-Rad AG50 X2 resin (Ca^{2+}, 200–400 mesh), monitoring the effluent with a Varian refractive index detector (Model No. 9-000098-00). D-Xylose dimethyl acetal emerged last from the resin as a well-resolved peak, which amounted to 25% after 30–75 min, and then decreased slowly.

D-*Xylose dimethyl acetal.* — D-Xylose (0.432 g) was added to methanol (10 ml) in which strontium chloride (0.8 g) and acetyl chloride (36 μl) had been dissolved, and the mixture was boiled for 40 min after the sugar had dissolved. The cooled solution was added to a solution of sodium carbonate (0.8 g) in water (30 ml). The precipitate was removed by centrifugation and washed with ethanol (2 × 10 ml). The solution was evaporated, the residue was extracted with hot anhydrous ethanol (10 ml) and filtered, and the filtrate was concentrated. The product was eluted, with recently boiled water, from a column (1.6 × 24 cm) of Bio-Rad AG50 X2 resin

(Ca^{++}, 200–400 mesh), collecting 3-ml fractions; the eluate was monitored with the refractive index detector.

Fractions 5–15 gave, on concentration, a mixture (0.37 g) of xylosides and inorganic material which was not investigated further.

Fractions 17–25 were combined, concentrated, and dried for 7 days over KOH at 23°/0.01 torr to give D-xylose dimethyl acetal (0.149 g, 26%), characterised[11] as its di-*O*-benzylidene derivative, m.p. 213–213.5°, $[\alpha]_D$ −6.9° (*c* 1.4, chloroform); lit.[19] m.p. 211°, $[\alpha]_D$ −8.3° (*c* 1.41, chloroform).

Glycosidation of L-*idose*. — A solution of 1,2-*O*-isopropylidene-β-L-idofuranose[20] (0.462 g) in water (0.5 ml) and trifluoroacetic acid (2 ml) was left at 23° for 20 min and then evaporated at 32°/30 torr, and water (5 ml) was added and evaporated. The residue was dissolved in water (5 ml), Dowex 1-X8 resin (3 ml, HCO_3^-) was added, and the mixture was aerated for 5 min. The resin was filtered off and washed with water (5 × 3 ml), the combined filtrate and washings were evaporated, and the residue was dried at 0.01 torr. The product (0.404 g), when examined by paper chromatography (BuOH–EtOH–H_2O, 4:1:2), showed a major product at R_F 0.27 and a very minor one at R_F 0.12, but no spot corresponding to 1,6-anhydro-L-idose.

A portion (0.295 g) of the product was dissolved in methanol (1 ml), a solution of strontium chloride (0.48 g) and acetyl chloride (22 μl) in methanol (5 ml) was added, and the mixture was boiled for 15 min and then worked up as described for D-xylose. The product was eluted with recently boiled water from a column (1.6 × 24 cm) of Bio-Rad AG50 X2 resin (Ca^{2+}, 200–400 mesh); the eluate was monitored with the refractive index detector. Eluted first (0–29 ml) was inorganic material (31 mg); eluted second (29–54 ml) was a mixture of compounds.

Eluted third (54–130 ml) was L-idose dimethyl acetal (55 mg, 15%), which was recrystallised from methanol (0.1 ml) and ethyl acetate (1 ml) to give material with m.p. 98–99°, $[\alpha]_D^{23}$ +29.4° (*c* 1.0, methanol). N.m.r. data (D_2O): δ 3.48 (s, 2 Me), 3.6–3.8 (m, 6 H), 4.52 (d, H-1, $J_{1,2}$ 6.9 Hz).

Anal. Calc. for $C_8H_{18}O_7$: C, 42.5; H, 8.0. Found: C, 41.9; H, 7.9.

The penta-acetate of L-idose dimethyl acetal had m.p. 88.5–90.5°. N.m.r. data ($CHCl_3$): δ 2.08–2.16 (3s, 5Ac), 3.35 (s, Me), 3.40 (s, Me), 4.04 (dd, H-6, $J_{5,6}$ 6.0, $J_{6,6'}$ −12.0 Hz), 4.28 (dd, H-6′, $J_{5,6'}$ 4.4 Hz), 4.34 (d, H-1, $J_{1,2}$ 5.8 Hz), 5.15 (dd, H-2?, $J_{2,3}$ 3.8 Hz), 5.25–5.45 (m, H-3,4,5).

Anal. Calc. for $C_{18}H_{28}O_{12}$: C, 49.5; H, 6.5. Found: C, 49.5; H, 6.5.

The mixture of compounds eluted second was chromatographed on a column (1.1 × 33 cm) of Dowex 1-X2 resin (HO^-, 200–400 mesh), eluting with freshly boiled water. Eluted first (0–50 ml) was material (8 mg) which was not further investigated.

Eluted second (50–100 ml) was methyl β-L-idofuranoside (105 mg, 33%; after drying at 0.01 torr for 2 days), $[\alpha]_D^{22}$ +88° (*c* 1.4, water). N.m.r. data (D_2O): δ 3.45 (s, Me), 5.01 (d, H-1, $J_{1,2}$ 3.7 Hz). N.m.r. data of the tetra-acetate ($CHCl_3$): δ 2.07 (2Ac), 2.13 (2Ac), 3.40 (s, Me), 4.17 (dd, H-6, $J_{5,6}$ 7.5, $J_{6,6'}$ −12 Hz), 4.26 (dd, H-6′,

$J_{5,6'}$ 5 Hz), 4.49 (dd, H-4, $J_{3,4}$ 8.0, $J_{4,5}$ 2.0 Hz), 5.03 (dd, H-2, $J_{1,2}$ 4.5, $J_{2,3}$ 8.0 Hz), 5.13 (d, H-1), 5.52 (t, H-3). The signal of H-5 is hidden by those of H-1 and H-2.

Eluted third (100–124 ml) was a mixture of glycosides (14 mg).

Eluted fourth (125–350 ml) was methyl α-L-idofuranoside (105 mg, 33%), $[\alpha]_D^{22}$ −75.5° (*c* 0.9, water). N.m.r. data (D_2O): δ 3.41 (s, Me), 3.59 (dd, H-6, $J_{5,6}$ 3.8 $J_{6,6'}$ −11.5 Hz), 3.72 (dd, H-6′, $J_{5,6'}$ 6.3 Hz), 3.98 (dd, H-5), 4.15 (apparent s, H-2,3,4), 4.88 (s, H-1). N.m.r. data of the tetra-acetate ($CHCl_3$): δ 2.06 (Ac), 2.11 (2Ac), 2.15 (Ac), 3.42 (s, Me), 4.07 (dd, H-6, $J_{5,6}$ 6.6, $J_{6,6'}$ −12 Hz), 4.34 (dd, H-6′, $J_{5,6'}$ 4.0 Hz), 4.53 (t, H-4, $J_{3,4}$ 6.1, $J_{4,5}$ 5.5 Hz), 4.89 (d, H-1, $J_{1,2}$ 1.6 Hz), 5.15 (dd, H-2, $J_{2,3}$ 2.6 Hz), 5.32 (dd, H-3), 5.32 (ddd, H-5).

N.m.r. spectra in the presence of lanthanide ions. — Gradual addition of europium nitrate to a solution of D-glucose dimethyl acetal in deuterium oxide caused all proton signals to shift upfield. When the solution is 0.27M in the acetal and 0.175M in europium, the methyl groups appear at δ 3.46 (instead of 3.49), H-1 at 4.28 (instead of 4.50), and H-2, H-3, and H-4 at 2.73, 2.10, and 2.45, respectively (instead of 3.6–3.9). The signal of H-2 is a doublet of doublets ($J_{2,3}$ ~3 Hz) and was identified by decoupling: its irradiation caused collapse of the H-1 doublet. The signals of H-4 (broad) and H-3 (narrow) were assigned by analogy with those in the spectrum of xylitol and D-glucitol[17]. Addition of praseodymium chloride to a solution of the acetal caused downfield shifts, but individual signals could not be identified. Europium chloride also caused upfield shifts in the spectrum of L-idose dimethyl acetal, but assignments could not be made; this molecule has two potential complexing sites.

The acidity of europium nitrate is sufficient to convert the acetals into furanosides, the idose derivative much faster than the glucose derivative. In 0.11M europium nitrate (pH ~3), the signals of L-idose dimethyl acetal had disappeared after 24 h, being replaced by those of methyl α- and β-L-idofuranoside in the ratio of ~1:2. Under the same conditions, D-glucose dimethyl acetal did not completely disappear after 2 weeks.

*Penta-*O*-acetyl-*D*-glucose dimethyl acetal.* — This compound was prepared[9] from D-glucose diethyl dithioacetal. Conversion of penta-*O*-acetyl-D-glucose diethyl dithioacetal into penta-*O*-acetyl-D-glucose dimethyl acetal was followed at hourly intervals by g.l.c. on 1% of ECNSS-M on Chromosorb W at 193° and was complete after 7 h. The retention time of starting material was 10.5 min and that of product was 4.0 min; two minor products having retention times of 5.7 and 6.8 min were observed, and were removed by chromatography on silica gel with ether as eluent. Penta-*O*-acetyl-D-glucose dimethyl acetal was obtained in crystalline form on removal of ether, and had m.p. 72°, $[\alpha]_D^{24}$ +13° (*c* 2.0, chloroform); lit.[9] m.p. 71–72°, $[\alpha]_D^{20}$ +12° (*c* 2.2, chloroform).

Acetylation of D-glucose dimethyl acetal, obtained from glycosidation of D-glucose in the presence of strontium chloride, with acetic anhydride and sodium acetate catalyst gave a product having physical constants, and infrared and n.m.r. spectra identical with those for D-glucose dimethyl dithioacetal.

Deacetylation of penta-*O*-acetyl-D-glucose dimethyl acetal with sodium methoxide gave a product identical with that obtained from the glycosidation of D-glucose in the presence of strontium chloride; m.p. 93–94°, $[\alpha]_D^{24}$ +16° (c 5.0, water); lit.[9] m.p. 94–95°, $[\alpha]_D^{20}$ +15° (c 3.1, water).

Penta-O-acetyl-D-galactose dimethyl acetal. — This compound, prepared by the two routes described for the corresponding D-glucose material, had m.p. 129°, $[\alpha]_D^{24}$ +16° (c 4.0, chloroform); lit.[12] m.p. 128–129°, $[\alpha]_D$ +16° (c 4, chloroform).

The same two procedures described above for the D-glucose derivative afforded D-galactose dimethyl acetal, m.p. 122°, $[\alpha]_D^{24}$ +16° (c 2.0, water), identical to lit. values[12].

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